Palmer LTER: Photoacclimation in a coastal phytoplankton bloom

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Phytoplankton blooms in antarctic waters show a strong coherence with oceanic density fields; high biomass is observed when mixing depths are shallow. It has been hypothesized that when phytoplankton are maintained in a stable light environment, cells photoacclimate and overcome the chronic light-limitation of growth associated with deeply mixing water columns (Mitchell et al. 1991). Phytoplankton photoacclimate by increasing cellular absorption capabilities ($\bar{a}_{ph}$:m^{-1}) and/or the quantum yield for carbon fixation (ϕ:mole carbon fixed per mole photons absorbed) (Kirk 1994,

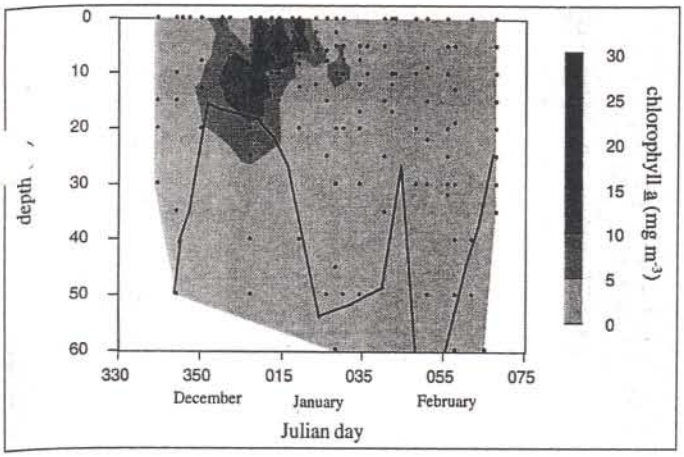

Figure 1. Contour of chlorophyll-*a* (mg m^{-3}) from December 1991 through February 1992 at LTER station B (Prézelin et al. 1992). Black circles indicate discrete samples. The mixed layer depth is denoted by a black line.

pp. 290–303); however, documenting photoacclimation in field populations is difficult. As part of the Palmer Long-Term Ecological Research (LTER) project, the temporal dynamics of a phytoplankton bloom was documented near Palmer Station (64°40'S 64°03'W) during the austral summer months of 1991–1992 (figure 1). This was an ideal data set for photoacclimation in phytoplankton because we were able to (1) follow the formation of bloom over time and (2) estimate $\bar{a}_{ph}$ and ϕ.

Water samples were collected from station B within the nearshore sampling grid of the LTER (Prézelin et al. 1992). *In* light levels (Q_{PAR}) were measured (Biospherical QL-100 ar irradiance meter), and discrete samples were transported to Palmer Station for analysis. Phytoplankton pigmentation was determined by high-performance liquid chromatography following the protocols described in Prézelin et al. (1992). Phytoplankton absorption was calculated as the summation of the products of *in vivo* absorption coefficients [$a_i^*(\lambda)$, figure 2*A*] and the volume-based concentrations [c_i, milligrams per cubic meter (mg m^{-3})] of the individual chlorophyll and carotenoid pigments (Bidigare et al. 1990). To calculate the absorption capabilities of the phytoplankton at depth, the reconstructed phytoplankton absorption spectra (figure 2*B*) must be weighted to the incident spectral irradiance [$Q(\lambda)$].

$$\bar{a}_{ph}' = \int_{400nm}^{700nm} a_{ph}(\lambda) \cdot Q(\lambda) d\lambda \Big/ Q_{PAR}$$

Measurements of the incident spectral irradiance were not available; thus, the absorption spectra were weighted to the spectral irradiance measured for oligotrophic coastal waters at the percentage of Q_{PAR} light depth where the LTER discrete water samples had been collected (Schofield et al. 1993; figure 2*C*). This results in an upper limit estimate of $\bar{a}_{ph}$ because $Q(\lambda)$ in oligotrophic waters will be shifted to the blue-green wavelengths of light where phytoplankton absorption is high. The wavelengths of maximum light transmission in a water column with high concentrations of phytoplankton pre-

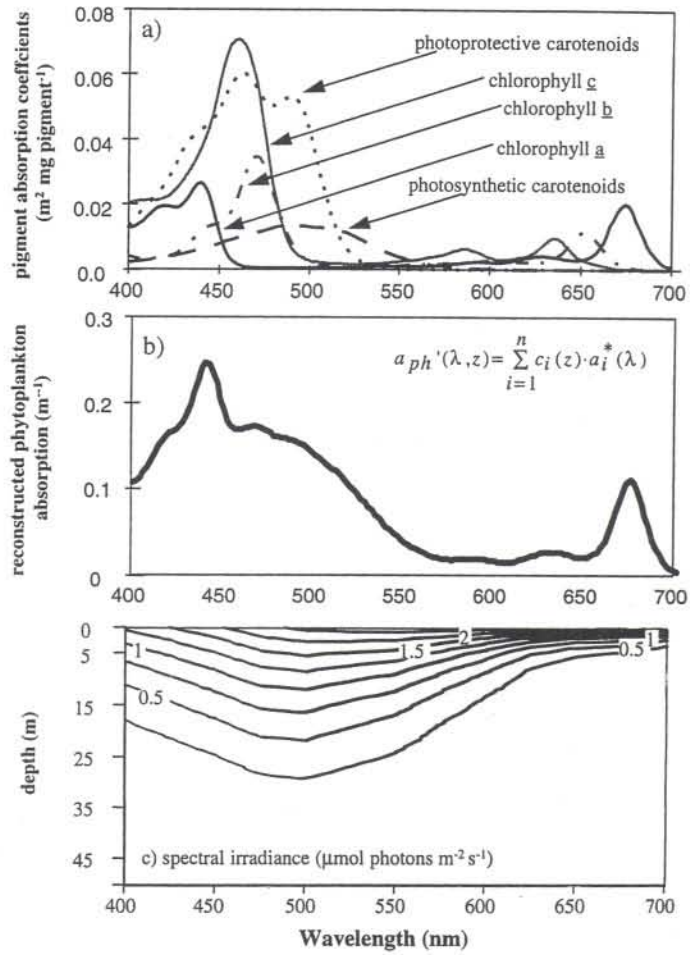

Figure 2. Procedure to calculate the spectrally weighted absorption coefficient for phytoplankton. *A.* The pigment-specific absorption coefficients for the chlorophylls and carotenoids measured by high performance liquid chromatography. *B.* An example of a reconstructed phytoplankton absorption spectra. *C.* The spectral irradiance profile used to weight the reconstructed absorption spectra to the incident light quality.

sent (as during the bloom) will be shifted to the green-orange wavelengths of light where cellular absorption is lower (figure 2*B*). Chlorophyll-specific $\bar{a}_{ph}$ showed no correlation with the phytoplankton bloom (figure 3*A*), a finding that provides circumstantial evidence that modifications in cellular absorption capabilities do not constitute the primary mode of photoacclimation for these phytoplankton; however, it should be emphasized that if cells increased all pigments in equal molar ratios then the chlorophyll-specific $\bar{a}_{ph}$ would remain relatively constant. We are currently assessing this possibility by studying the temporal variability in the accessory pigment-chlorophyll-*a* ratios.

Values of ϕ were estimated from productivity rates calculated from photosynthesis-irradiance curves by using procedures described by Schofield et al. (1993). Values of ϕ increased prior to the phytoplankton bloom (figure 3*B*) and values approached theoretical maximum values as the mixed layer depth shallowed. This suggests that the regulation of ϕ was a primary mode of photoacclimation. Later in the season, as the mixed layer depth shallowed, the values of ϕ increased. These data suggest that photoacclimation in these phytoplankton was constrained by water column mixing, which is consistent

with the hypothesis that shallow mixing depths provide a relatively stable light environment that allows algae to photoacclimate on the timescale of 1–2 days.

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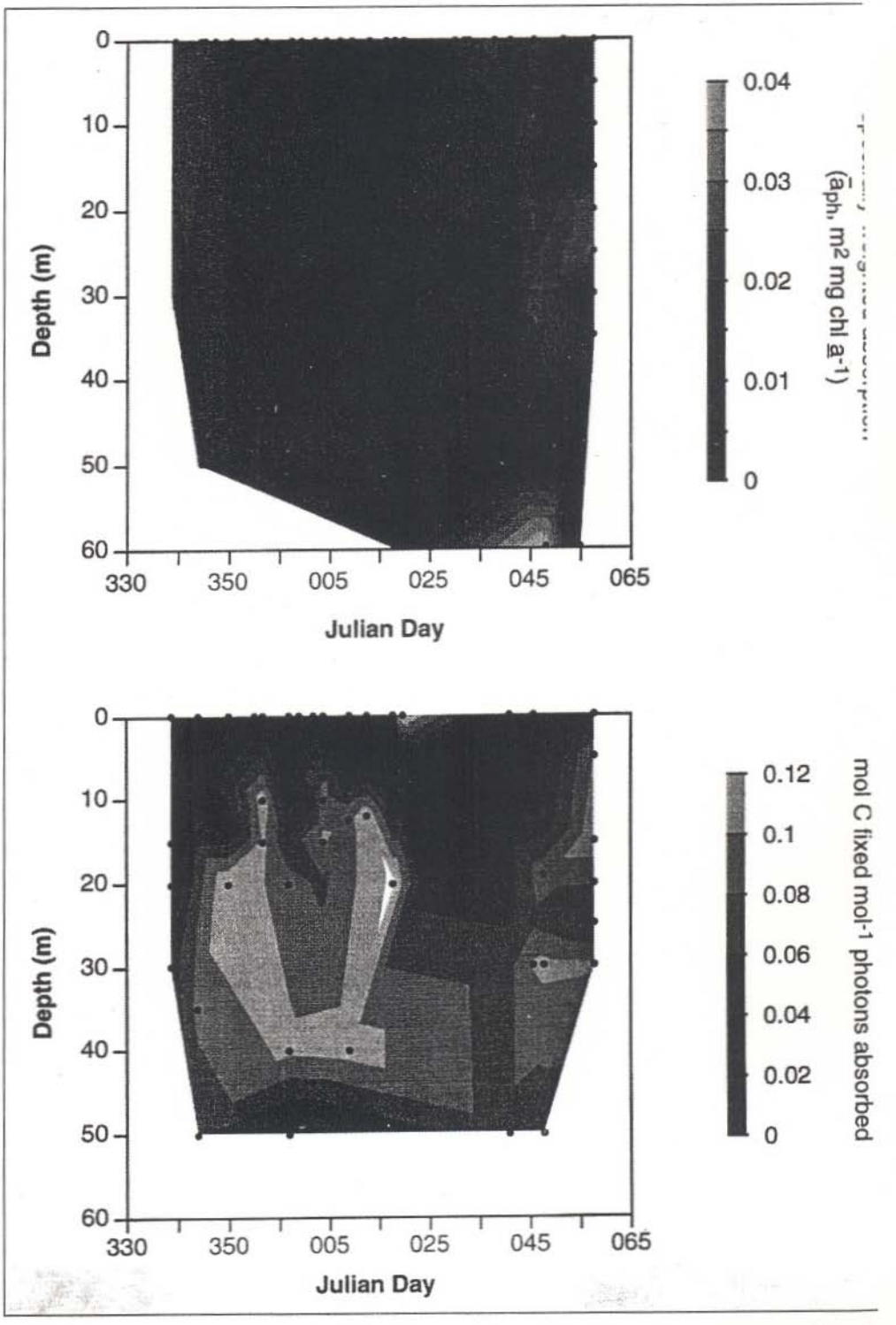

Figure 3. Contours of (*A*) the chlorophyll-specific spectrally weighted absorption coefficient (m^2 mg ch and (*B*) the operational quantum yield for carbon fixation.